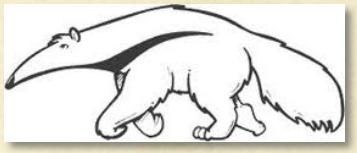
Neutralino Annihilation in the pMSSM: Impact of *Fermi*-LAT and CTA

Randy Cotta - UC Irvine



In collaboration with:
Matthew Cahill-Rowley, Alex Drlica-Wagner, Ahmed Ismail, Matthew Wood
Stefan Funk, JoAnne Hewett, Tom Rizzo

Snowmass Cosmic Frontier Workshop @ SLAC, March 2013

Questions...

- Which experiment will make the first discovery of $\tilde{\chi}_1^0$?
- What will we learn about $\tilde{\chi}_1^0$ when we see something?

Answers...

Broader pMSSM Complementarity: Tom Rizzo, next!

- The p(henomenological)MSSM allows robust study of the possibilities using diverse sample of realistic SUSY models. Full details for each model: predictions for any experiment without theoretical over-simplification
- Collaboration with *Fermi*-LAT and CTA members (A. Drlica-Wagner, Matthew Wood, Stefan Funk) to do an accurate sensitivity analysis on each and every pMSSM model.

Questions...

- Which experiment will make the first discovery of $\tilde{\chi}_1^0$?
- What will we learn about $\tilde{\chi}_1^0$ when we see something?

Will we even have an experiment capable of discovering $\tilde{\chi}_1^0$?

Answers...

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~ The p(henomenological)MSSM ~

The p(henomenological)MSSM:

- Take the ~120 free parameters in the MSSM, subtract those which are highly constrained by experiment (mostly: new flavor pars.), end up with a 19-dimensional subspace: the pMSSM. Considerably more general than mSUGRA/CMSSM

- Scan the space and subject all points to a rigorous battery of constraints. We are the ONLY collaboration that employs realistic collider bounds in a >7-8 dimensional SUSY space.

- We have ~225,000 pMSSM models with $\tilde{\chi}_1^0$ DM. Sparticle masses are scanned up to 4 TeV giving $\tilde{\chi}_1^0$ masses up to ~2TeV. WMAP relic density is taken as an upper bound on the $\tilde{\chi}_1^0$ relic density.

- This is the 2nd generation of pMSSM models: we can observe the impact of the last ~ 4 years of experiments.

See also pMSSM talks by:
Matthew Cahill-Rowley, Alex Drlica-Wagner, Ahmed Ismail and Tom Rizzo

Indirect Detection: Messengers & Targets

Messengers: γ's, ν's, anti-particles, ...

IceCube/DeepCore
(See: R.C., D. Grant,
F. Halzen, talks)

(although, see Y. Nomura talk)

Very small signal predicted (MSSM),
Extra complication: propagation.
Ambiguous discoveries...

Clean signal (trivial propagation) many potential targets and
experiments approaching sensitivities relevant for neutralino DM.

Targets:

"Direct Detection for $\langle \sigma v \rangle$"

Milky Way dwarf spheroidal galaxies:

Extremely DM dominated. DM content from stellar kinematics no intrinsic γ background, Multiple dwarfs can give independent confirmations of discovery.

Milky Way Galactic Center:

Large DM density^2 gives potentially very large signals though much larger uncertainties
(relying on DM simulations where baryons are important and many background gamma-ray sources)

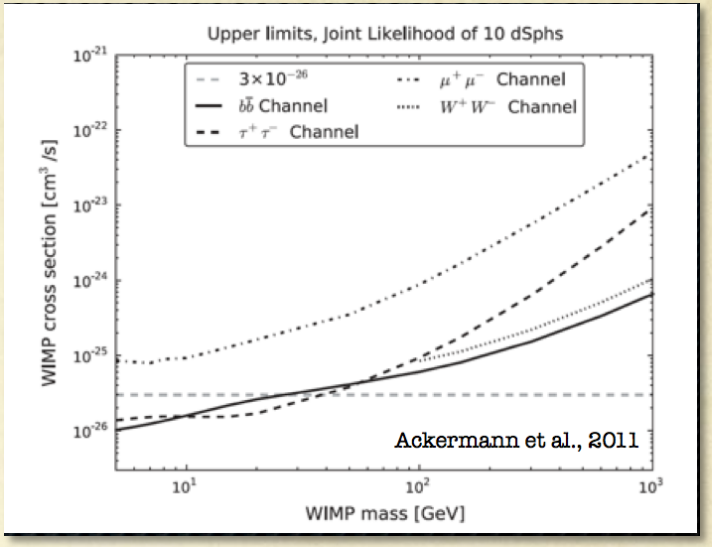
Indirect Detection: Tools

See Alex Drlica-Wagner and Matthew Wood talks!

Fermi-LAT:

Combined likelihood analysis of multiple dwarfs using 2-yrs of data similar to (and validated against) the LAT dwarf PRL

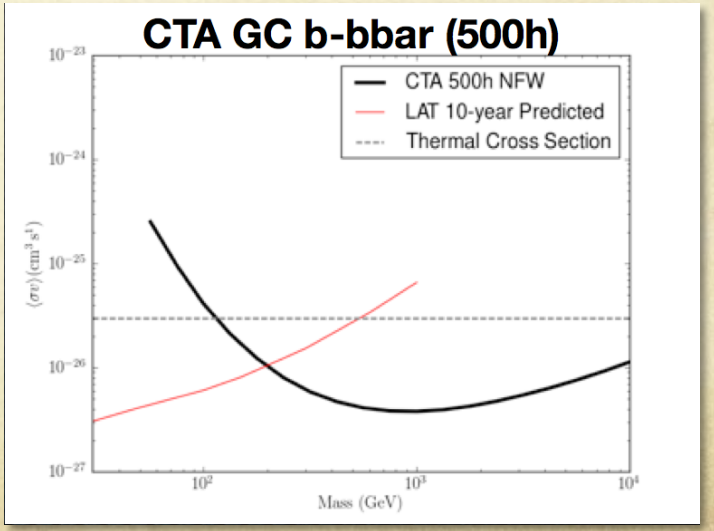
Estimate improvement by a factor of ~10 (more data, improved LAT analyses, DES discovery of more faint dwarfs in the southern sky)



A Possible CTA:

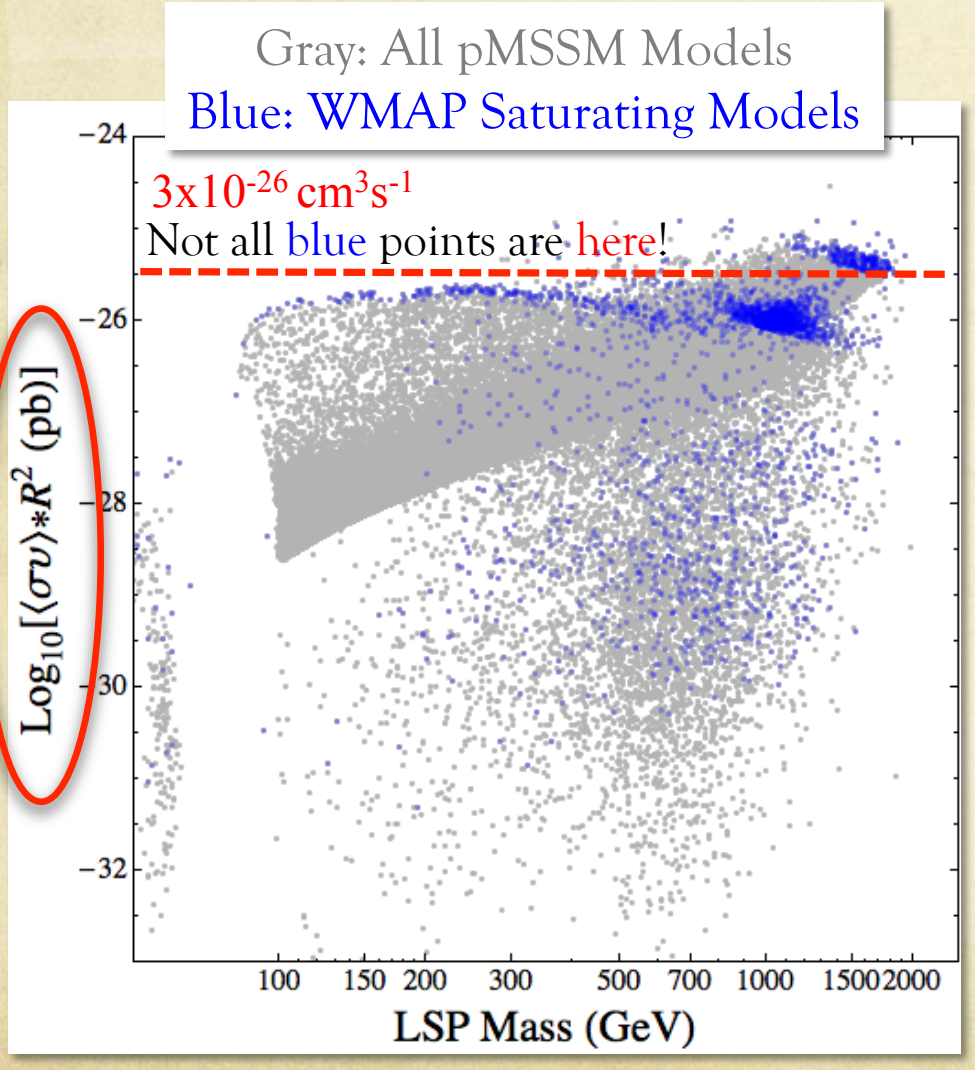
Configuration including US contributed 36 mid-sized telescopes.

Projected limits based on 500hr observation of an annular region around the Galactic Center



Basic Results...

Annihilations and Relic Density...



WMAP CDM relic density measurement is only an upper-bound on pMSSM...

All plots assume thermal relic density...

Relic density is really important for indirect searches:

$$R = \frac{\Omega h^2|_{LSP}}{\Omega h^2|_{WMAP}}$$

$$\langle \sigma \upsilon \rangle \sim 1/R$$

$$\langle \sigma \upsilon \rangle_{therm} = \langle \sigma \upsilon \rangle R^2 \sim R$$

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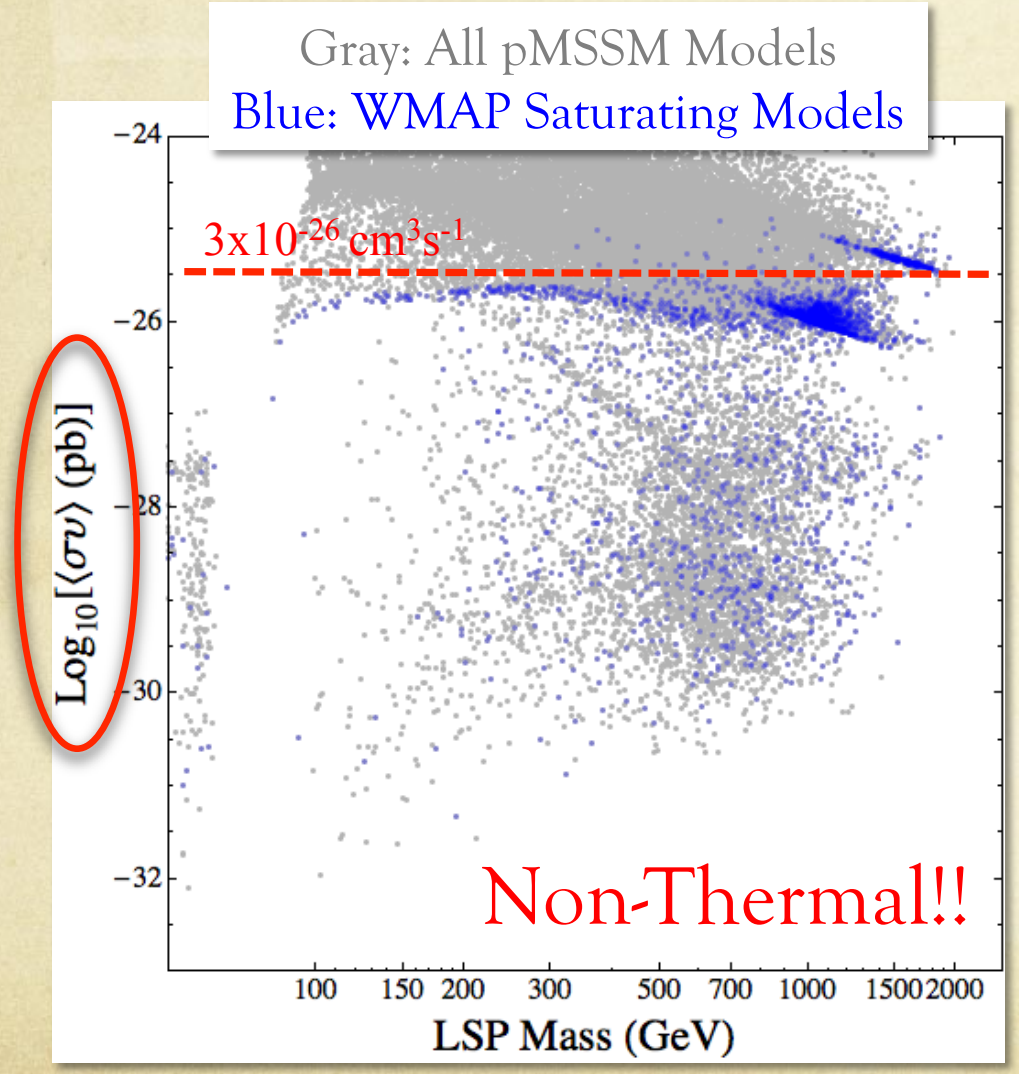

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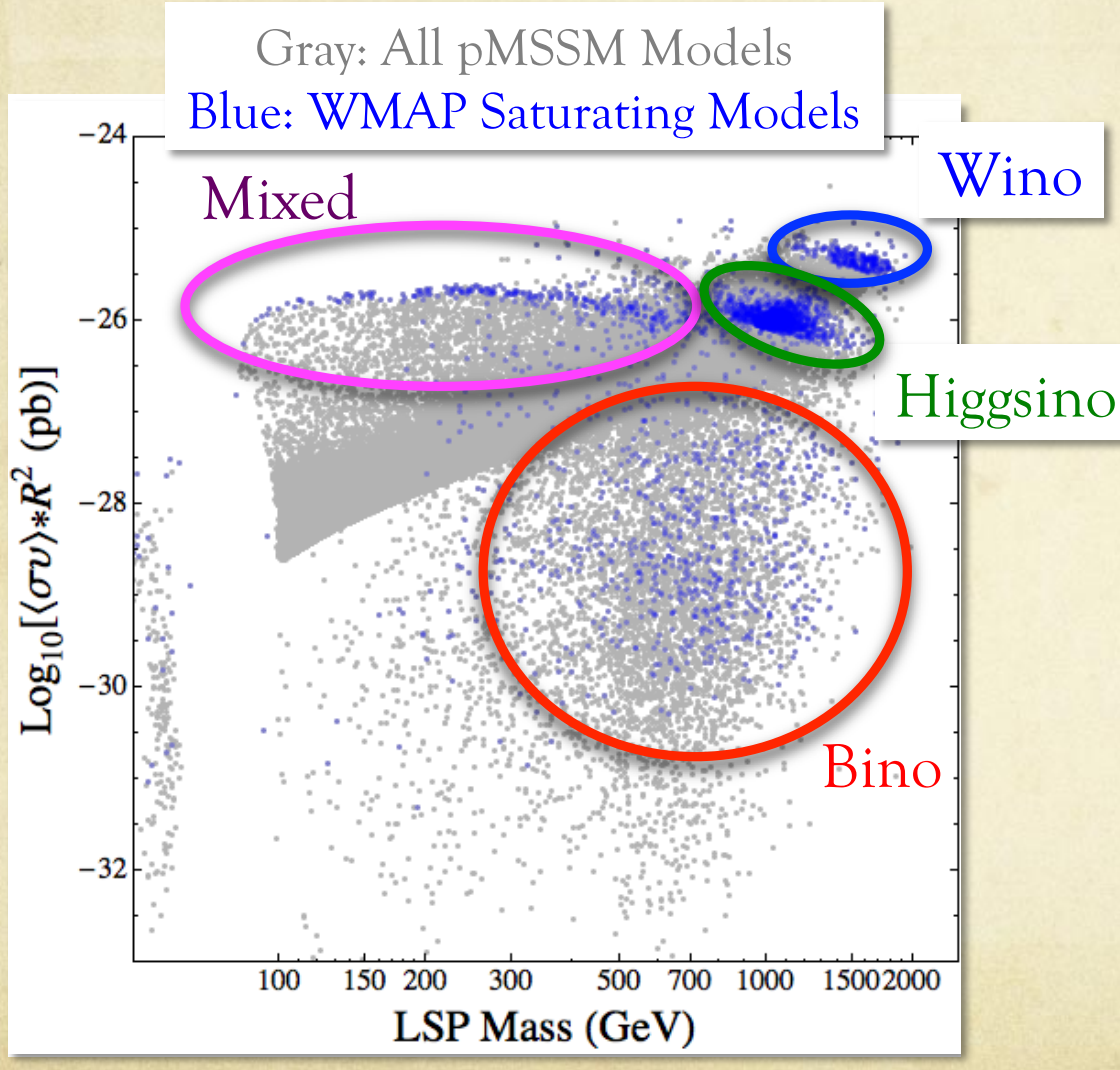

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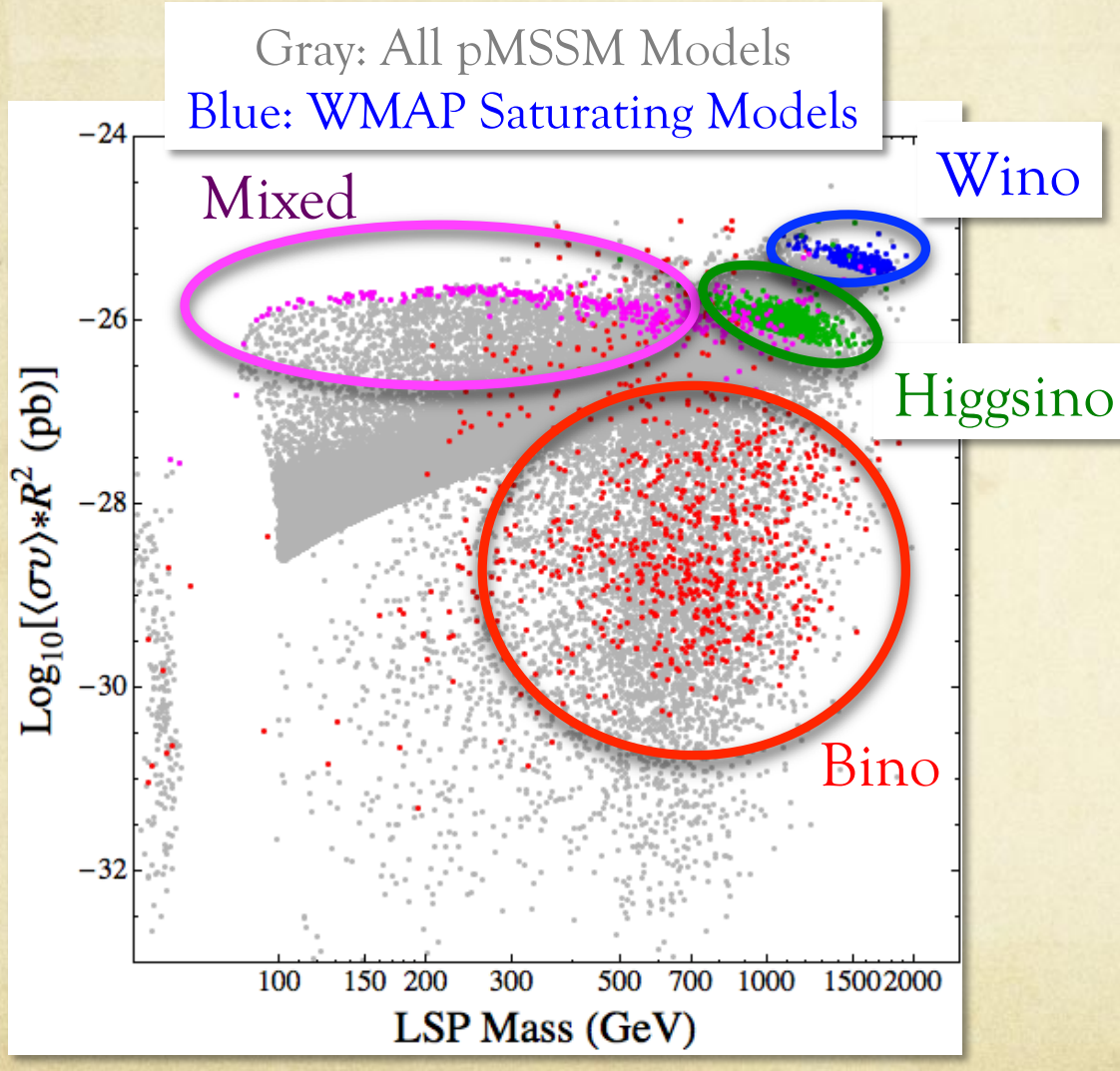

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Fermi-LAT Dwarf Observations: Basic Results

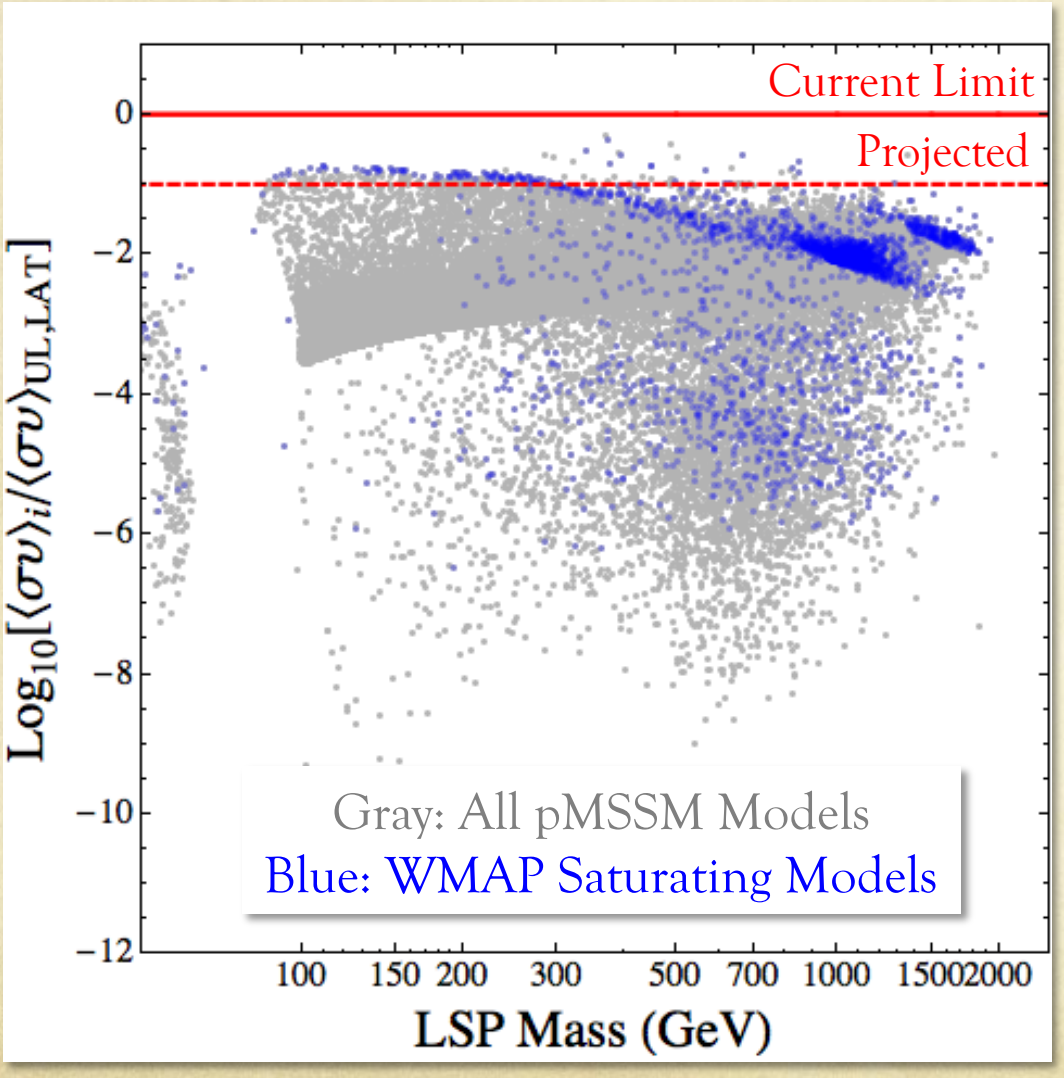

Figure of merit:

$$\frac{\langle\sigma v\rangle_{\mathrm{therm}}}{\langle\sigma v\rangle_{\mathrm{UL,\,LAT}}}$$

calculated using the LAT analysis and the gamma spectrum appropriate for each individual pMSSM model.

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Well-Tempered neutralinos with masses below ~300GeV

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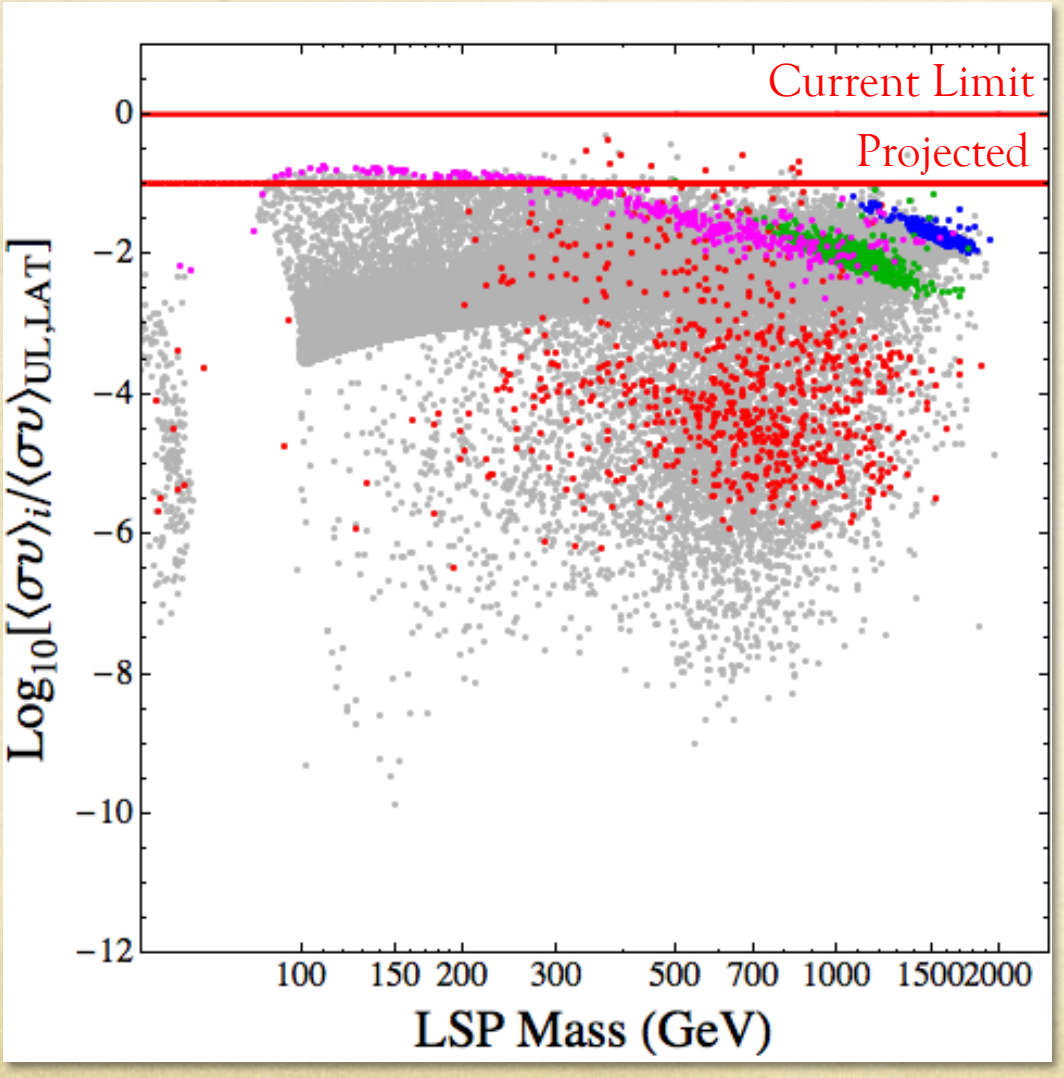

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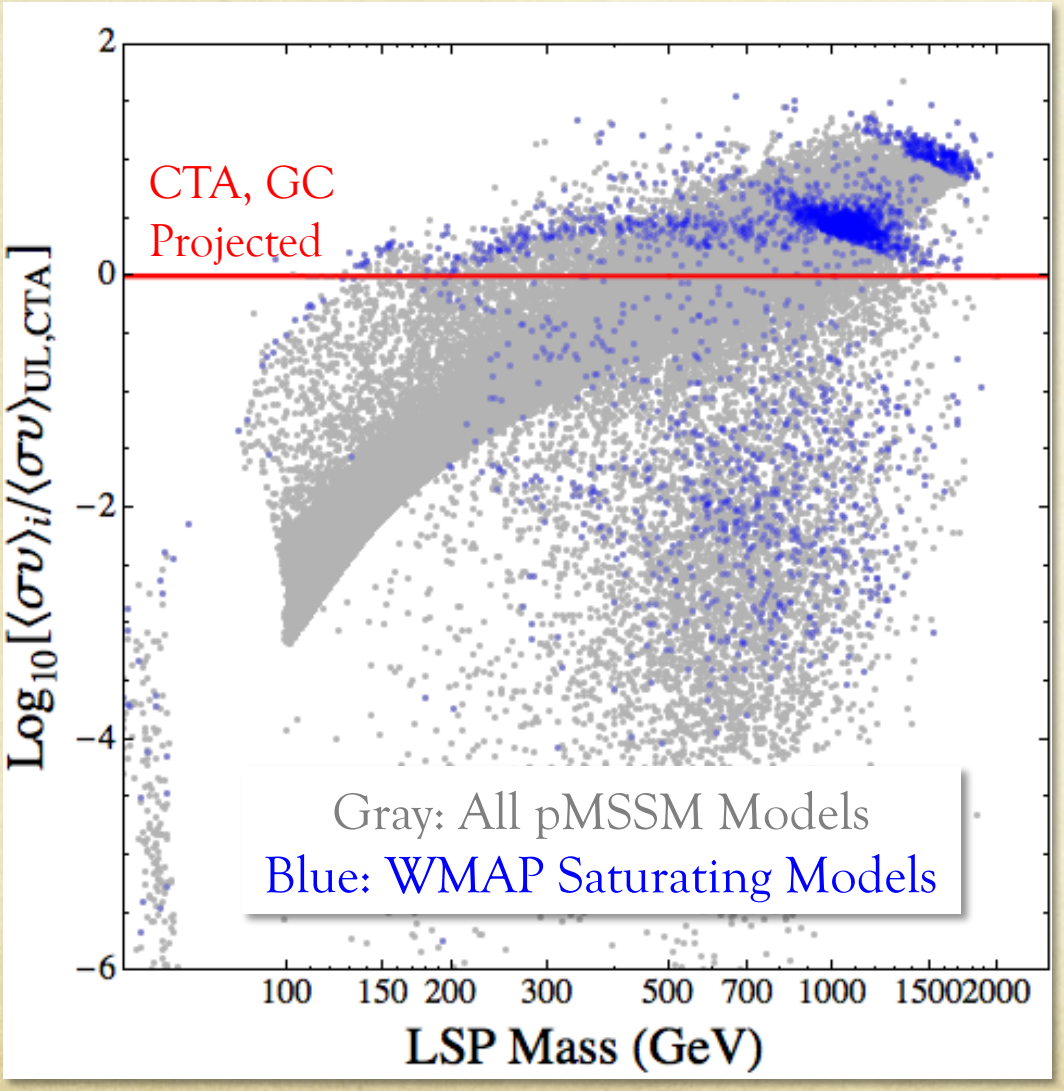
CTA Gal. Cen. Projection: Basic Results



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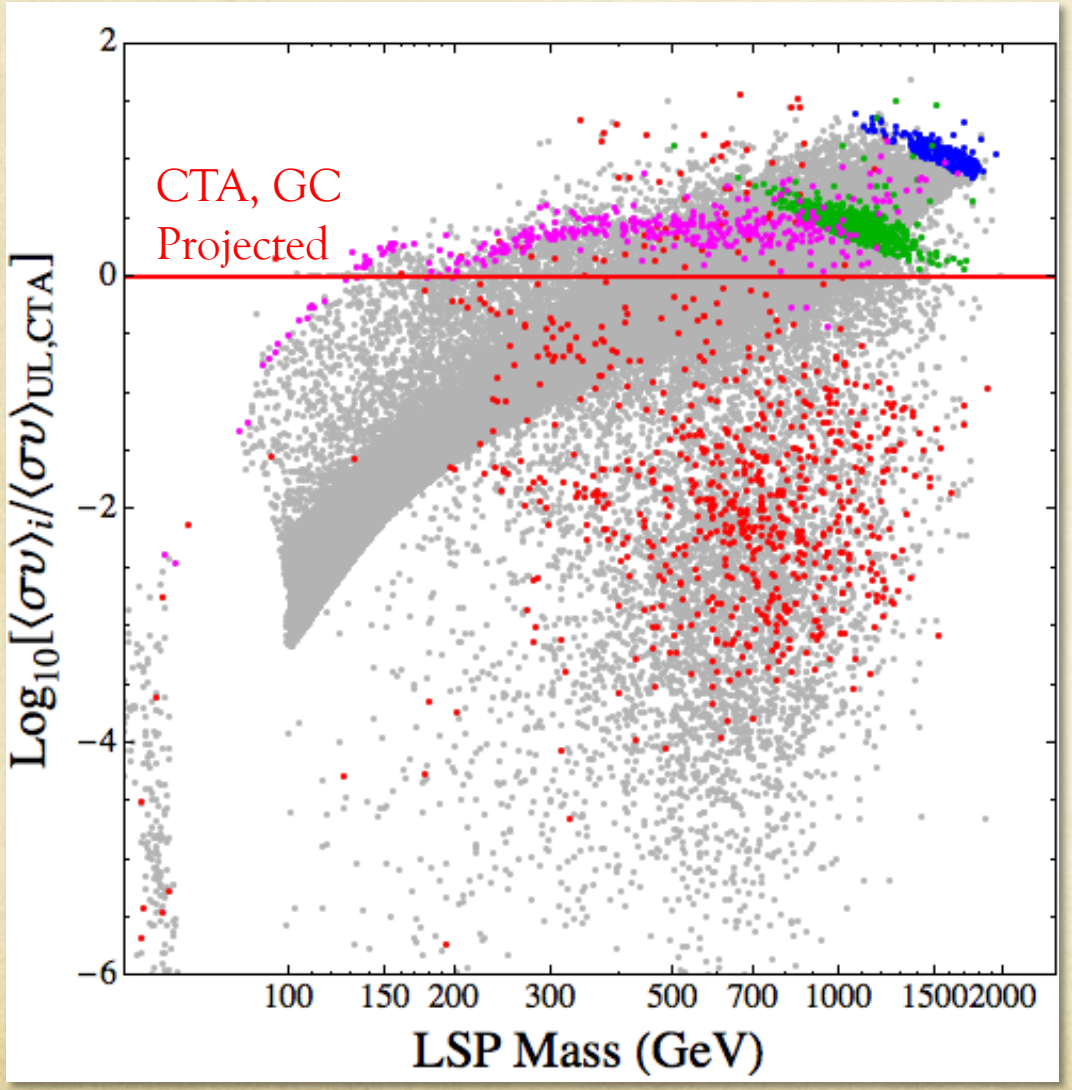

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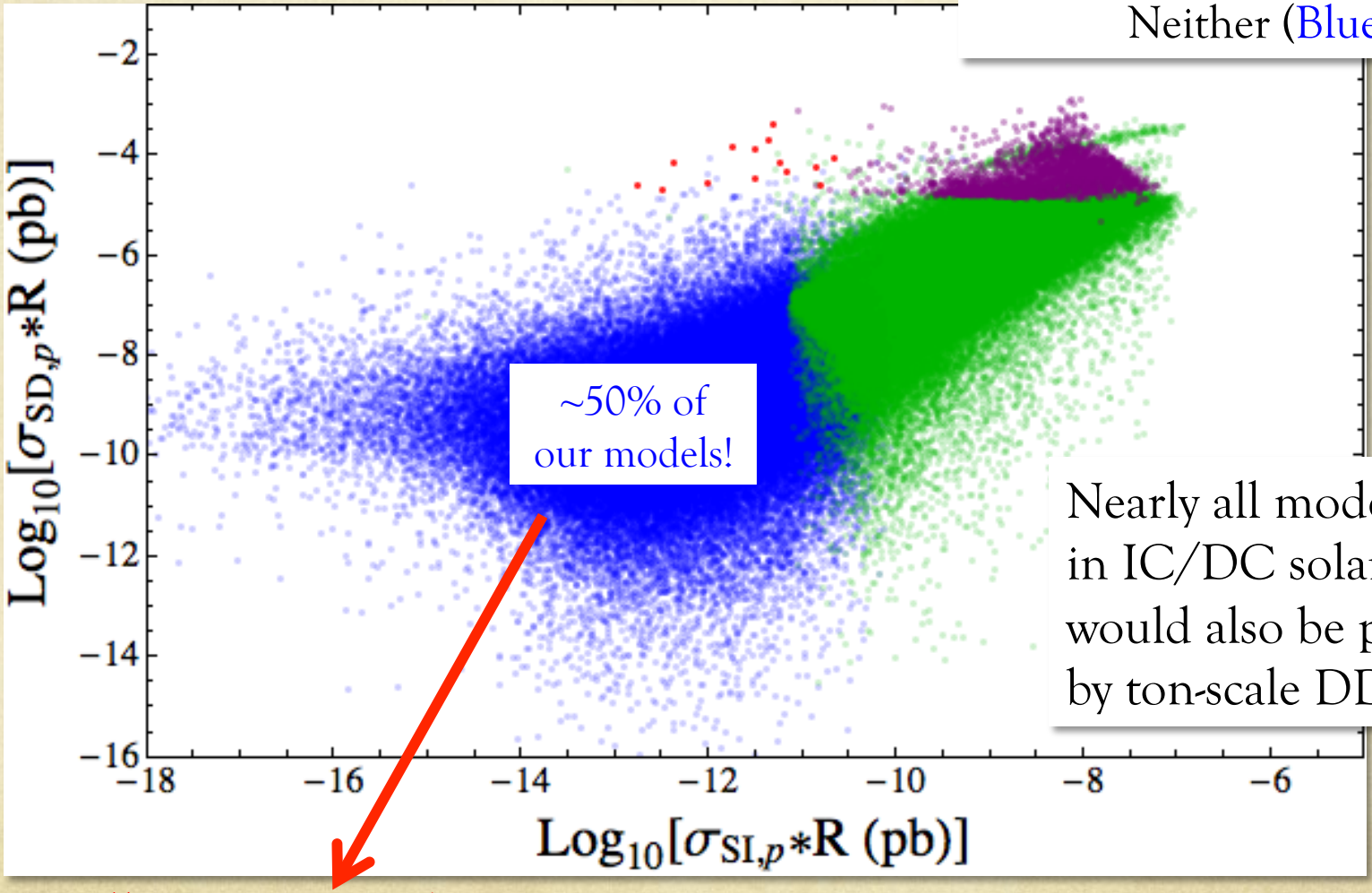
More Importantly:

CTA covers ~ ALL WMAP saturating neutralinos except for p-wave annihilating binos

From My Last Talk...

Excluded by...
IC/DC + LZ (Purple),
LZ only (Green),
IC/DC only (Red),
Neither (Blue),



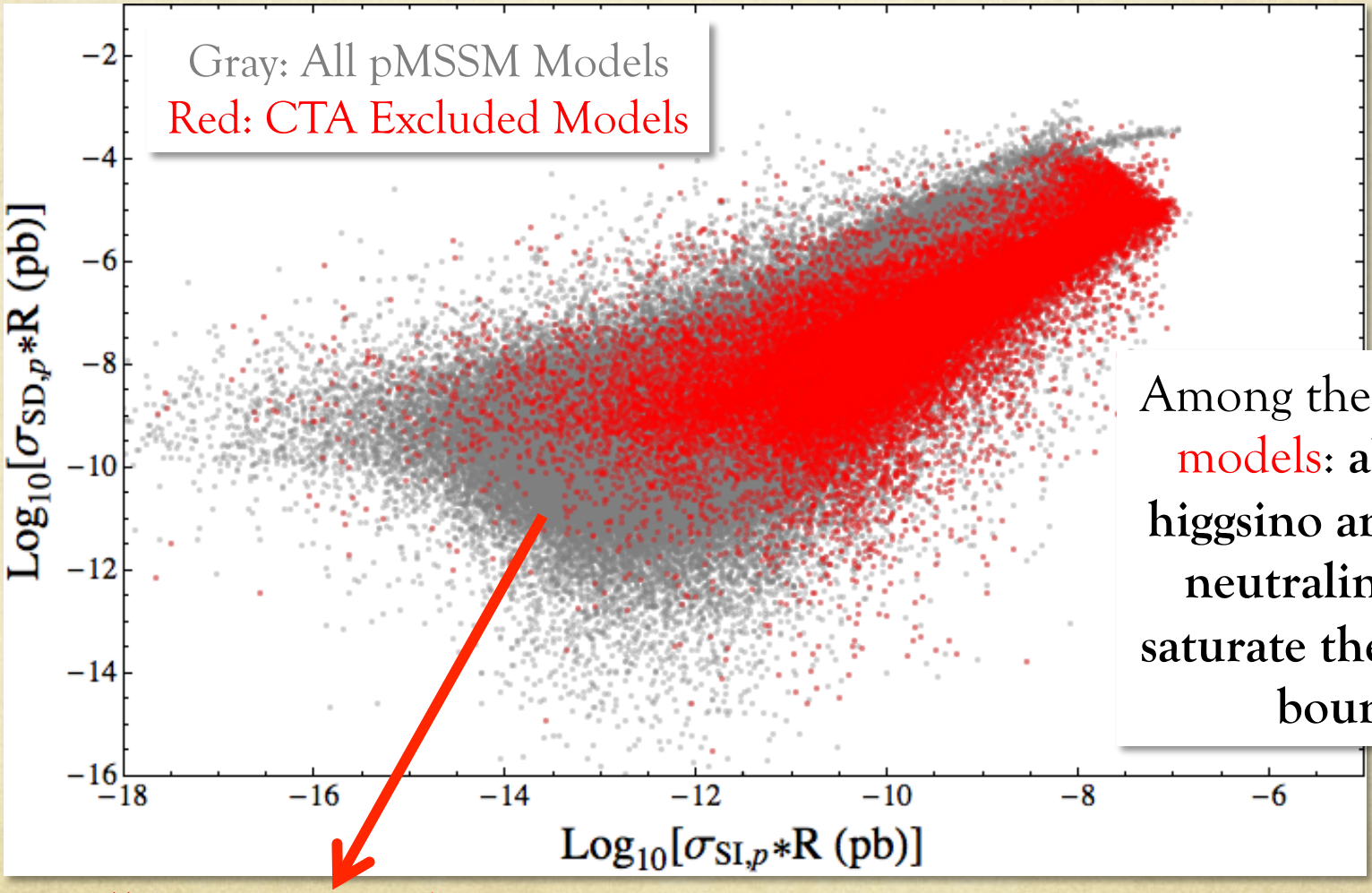
Nearly all models seen in IC/DC solar search would also be probed by ton-scale DD expts.

How will we ever see these??? See R.C., A. Drlica-Wagner, A. Ismail & T. Rizzo Talks

(Most are very hard to see in DD and even at the LHC... answer is: with CTA)

CTA Probes Models with low scattering cross-sections

These models would be very hard to see with any other kind of experiment!



Among the excluded models: **all wino, higgsino and mixed neutralinos that saturate the WMAP bound.**

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Conclusions...

Direct and Collider searches are cutting deep into interesting SUSY parameter space... it is not clear that we are really planning for the same capability to place robust and relevant constraints via Indirect Detection.

Direct and Collider searches are cutting deep into interesting SUSY parameter space... but they'd completely miss 50% of our pMSSM model set (important models!)

Gamma-Ray bounds are starting to have fantastic influence on our theoretical expectations for DM and are an important complement to direct and collider searches...
Is it okay to leave the job half done?